POWER SPECTRAL DENSITY MASKS FOR IMPROVED SPECTRAL COMPATIBILITY

Related Applications

[0001] The present invention claims priority to U.S. Provisional Application Nos. 60/491,268 filed July 31, 2003 and 60/426,796 filed November 18, 2002, the contents of which are incorporated herein by reference in their entirety.

[0002] This application is related to copending U.S. Patent Applications titled "SYSTEM AND METHOD FOR SELECTABLE MASK FOR LDSL," filed January 22, 2003 (Attorney Docket No. 56162.000456) which claims priority to U.S. Provisional Application No. 60/441,351, "ENHANCED SMART DSL FOR LDSL," (Attorney Docket No. 56162.000483), "ENHANCED SMART DSL FOR LDSL," (Attorney Docket No. 56162.000484) which claim priority to U.S. Provisional Application No. 60/488,804 filed July 22, 2003, all filed concurrently herewith.

BACKGROUND OF THE INVENTION

[0003] Field of the Invention

[0004] This invention relates to digital subscriber lines (DSL) and to smart systems for implementing Long reach Digital Subscriber Lines (LDSL).

[0005] Description of Related Art

[0006] High level procedures for meeting stated objectives for Long reach Digital Subscriber Line (LDSL) transmissions are disclosed. Some objectives for LDSL have been defined in publications available from standards organizations such as the International Telecommunications Union (ITU). For example, ITU publications OC-041R1, OC-045, OC-073R1, OJ-030, OJ-036, OJ-060, OJ-061, OJ-062, OJ-200R1, OJ-200R2, OJ-201, OJ-60R1, OJ-60R2 and OJ-210 set forth some LDSL objectives. Other objectives, standards and criteria for LDSL are also possible and may be accommodated by the disclosed inventions.

[0007] One LDSL target objective is to achieve a minimum payload transmission of 192 kb/s downstream and 96 kb/s upstream on loops having an equivalent working

length of 18 kft 26 gauge cable in a variety of loop and noise conditions. One difficulty in achieving these target transmission rates is the occurrence of crosstalk noise.

[0008] The crosstalk noise environments that may occur for the above bit rate target objective are varied. For example, noise environments may include Near-end cross talk (NEXT), Far-end cross talk (FEXT), disturbance from Integrated Services Digital Networks (ISDN), High Speed Digital Subscriber Lines (HDSL), SHDSL, T1, and Self-disturbers at both the Central Office (CO) and Customer Premise Equipment (CPE) ends. NEXT from HDSL and SHDSL tend to limit the performance in the upstream channel, while NEXT from repeatered T1 AMI systems tend to severely limit the downstream channel performance. An additional source of noise is loops containing bridged taps that degrade performance on an Asymmetric Digital Subscriber Line (ADSL) downstream channel more so than the upstream channel.

[0009] Another drawback of existing systems is that it appears very difficult to determine a single pair of Upstream and Downstream masks that will maximize the performance against any noise-loop field scenario, while ensuring spectral compatibility and, at the same time, keeping a desirable balance between Upstream and Downstream rates.

[0010] One approach for LDSL relies on different Upstream and Downstream masks exhibiting complementary features. Realistically, all these chosen masks are available on any LDSL Platform. At the modem start up, based on a certain protocol, the best Upstream-Downstream pair of masks is picked up. Whether the best pair is manually chosen at the discretion of the operator, or automatically selected, this concept is identified as "smart DSL for LDSL".

[0011] There are many reasons to implement smart DSL. For example, non-smart DSL systems may implement a single mask for upstream and downstream transmissions. A drawback with this approach is that the use of a single mask may prevent LDSL service in areas of the United States dominated by T1 noise.

[0012] In addition, the use of a single mask is a drawback because the existence of other spectrally compatible masks cannot be ruled out. LDSL service providers will want to have access to an array of mask/tools provided they are spectrally compatible. Service providers may decide to use only one mask according to the physical layer conditions, or any combination of masks for the same or other reasons.

[0013] Another advantage of Smart DSL is that it is a good way to handle providing LDSL services in different countries. For example, so far, LDSL work has focused on SBC requirements. As a result, it is risky of, for example, a US-based LDSL provider to rely on the ability to apply any masks that pass SBC tests to Europe, China or Korea. LDSL is a difficult project and essential for all the countries. Therefore, any scheme for LDSL standardization that takes into account merely SBC physical layer and cross talk requirements may jeopardize the ADSL reach extension in non-standard LDSL countries. Other drawbacks of current systems also exist.

SUMMARY OF THE INVENTION

[0014] A "Smart DSL System" for addressing the performance objectives of LDSL and examples of smart systems for LDSL are disclosed.

[0015] In accordance with some embodiments of the invention there is provided a method for implementing smart DSL for LDSL systems. Embodiments of the method may comprise defining a candidate system to be implemented by an LDSL system, optimizing criteria associated with the candidate system, and selecting a candidate system to implement in an LDSL system.

[0016] In some embodiments the method may further comprise determining features of upstream transmission and determining one or more of: cut-off frequencies, side lobe shapes, overlap, partial overlap or FDD characteristics. Other advantages and embodiments of the invention are also disclosed in the following sections.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Figure 1 is a graph illustrating peak values for U1 and D1 PSD masks according to embodiments of the invention.

[0018] Figure 2 is a graph illustrating peak values for U2 and D2 PSD masks according to embodiments of the invention.

[0019] Figure 3 is a graph illustrating average values for U3 and D3 PSD templates according to embodiments of the invention.

[0020] Figure 4 is a bar chart illustrating upstream rate, noise case #1, for ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0021] Figure 5 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0022] Figure 6 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0023] Figure 7 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0024] Figure 8 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0025] Figure 9 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0026] Figure 10 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0027] Figure 11 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0028] Figure 12 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0029] Figure 13 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0030] Figure 14 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0031] Figure 15 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0032] Figure 16 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0033] Figure 17 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0034] Figure 18 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0035] Figure 19 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0036] Figure 20 is a bar chart illustrating upstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0037] Figure 21 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0038] Figure 22 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0039] Figure 23 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0040] Figure 24 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0041] Figure 25 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0042] Figure 26 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0043] Figure 27 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0044] Figure 28 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0045] Figure 29 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0046] Figure 30 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0047] Figure 31 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0048] Figure 32 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0049] Figure 33 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0050] Figure 34 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0051] Figure 35 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0052] Figure 36 illustrates a flow diagram for selecting a pair of masks in a smart DSL system in accordance with embodiments of the invention.

[0053] Figure 37 is a state diagram illustrating options for selecting a pair of masks in a smart DSL systems in accordance with embodiments of the invention.

[0054] Figure 38 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0055] Figure 39 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0056] Figure 40 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0057] Figure 41 illustrates LDSL nominal values for downstream wide mask and G.992.1 upstream mask in accordance with embodiments of the invention.

[0058] Figure 42 illustrates LDSL downstream narrow mask and G.992.1 upstream mask in accordance with embodiments of the invention.

[0059] Figure 43 illustrates a peak values quad spectrum mask plot in accordance with embodiments of the invention.

[0060] Figure 44 illustrates G.992.5 peak values upstream mask plot in accordance with embodiments of the invention.

[0061] Figure 45 illustrates extended overlap quad spectrum overlap downstream mask, plot based on peak values in accordance with embodiments of the invention.

[0062] Figure 46 illustrates extended overlap quad spectrum upstream mask plot based on peak values in accordance with embodiments of the invention.

[0063] Figure 47 illustrates quad spectrum reduced overlap downstream mask plot based on peak values in accordance with embodiments of the invention.

[0064] Figure 48 illustrates extended upstream mask plot based on peak values in accordance with embodiments of the invention.

[0065] Figure 49 illustrates OL quad spectrum downstream mask plot, peak values in accordance with embodiments of the invention.

[0066] Figure 50 illustrates G.992.5 peak values upstream mask plot in accordance with embodiments of the invention.

[0067]

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0068] Smart DSL Concept for LDSL.

[0069] This section defines a Smart DSL concept for LDSL. In some embodiments, operating with smart DSL systems for LDSL may include the below listed steps. The first and second steps may be completed, in some embodiments, during a standardization process and other steps may be performed during a modem's handshake/initialization phase in order to optimize the performance for any type of loops and noises.

[0070] Step 1. Smart DSL Systems members for LDSL (S).

[0071] In some embodiments it is preferable to complete step 1 during standardization processes. Alternatively, step 1 may be performed off line, for example, if no standardization is at stake.

[0072] In some embodiments, the first step consists of defining candidate systems that aim to be picked up based on optimization criteria defined below. Typically, these candidate systems may exhibit sufficient versatility features for both Upstream and Downstream spectra, such as cut off frequencies, side lobes shapes, overlap, partial overlap, FDD characteristics, etc.

[0073] In some embodiments it may be desirable for candidate systems to also meet additional constraints. For example, an additional constraint may be that no new channel coding scheme should be considered in the candidate systems. In this manner, smart DSL systems in accordance with the invention exhibit several degrees of freedom that are summarized in what follows by parameter set S.

[0074] Step 2. Optimization criteria (C).

[0075] In some embodiments, it is preferable that the second step be completed during the standardization process. Alternatively, the second step may be completed off line if no standardization is at stake.

[0076] The second step comprises defining optimization criteria. Optimization criteria drive smart DSL systems members definition and, of course, the performance outcomes. For some embodiments, optimization criteria (C) may be summarized as covering Upstream and Downstream performance targets. In addition, optimization criteria may cover the margin within which performance targets should be met, such as, whether the deployment is Upstream or Downstream limited. The last point is important since often, in order to keep the optimization process simple priority should be given to Upstream or Downstream channels.

[0077] In some embodiments, optimization criteria may also comprise spectral compatibility requirements. This criteria may also include assumptions about neighboring services. Other optimization criteria are also possible.

[0078] Step 3. Choice of an optimal system amongst the smart DSL systems candidates (S*).

[0079] In some embodiments it may be preferable to complete step 3 during handshake/initialization. Completing step 3 during handshake/initialization may enable better handling of any type of loops and noise/cross talk conditions. Alternatively, this step could be completed off line, for example, if the operator has accurate prior knowledge of loops and noise conditions.

[0080] In some embodiments, completion of step 3 may be as simple as picking up one of two masks already defined. In other embodiments, completion of step 3 may comprise tuning a continuous parameter such as a cut off frequency. Other methods of completing step 3 are also possible.

[0081] In some embodiments, the outcome of step 3 may comprise an optimal system (S*) that will be run by the modem in the conditions that lead to its optimality.

[0082] Two Examples of Smart DSL system for LDSL, based on SBC requirements.

[0083] Example 1: Definition of the Masks to be used in the two smart systems.

[0084] Three Upstream masks U1, U2, U3 and three Downstream masks D1, D2, D3 are used in what follows to define embodiments of smart systems. U1 (dashed line) and D1 (solid line) masks are plotted in Figure 1. Note that in this section the masks for peak values are defined. As defined by some standards, the PSD templates, or average PSD values, are 3.5 dB lower than the mask values. Tables 1 and 2 show some values for U1 and D1 (respectively) according to some embodiments of the invention.

Frequency Band f (kHz)	**Equation for the PSD mask (dBm/Hz)**
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f \leq 25.875$	$-92.5 + 23.43 \times \log_2(f/4)$;
$25.875 < f \leq 60.375$	–29.0
$60.375 < f \leq 90.5$	$-34.5 - 95 \times \log_2(f/60.375)$
$90.5 < f \leq 1221$	–90
$1221 < f \leq 1630$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
$1630 < f \leq 11\,040$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of –50 dBm

Table 1. U1 PSD Mask Definition, peak values

Frequency Band f (kHz)	Equation for the PSD mask (dBm/Hz)
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBm
$4 < f \leq 25.875$	$-92.5 + 20.79 \times \log_2(f/4)$
$25.875 < f \leq 81$	–36.5
$81 < f \leq 92.1$	$-36.5 - 70 \times \log_2(f/81)$
$92.1 < f \leq 121.4$	–49.5
$121.4 < f \leq 138$	$-49.5 + 70 \times \log_2(f/121.4)$
$138 < f \leq 353.625$	$-36.5+0.0139\times(f-138)$
$353.625 < f \leq 569.25$	–33.5
$569.25 < f \leq 1622.5$	$-33.5 - 36 \times \log_2(f/ 569.25)$
$1622.5 < f \leq 3093$	–90
$3093 < f \leq 4545$	–90 peak, with maximum power in the $[f, f+1$ MHz$]$ window of $(-36.5-36 \times \log_2(f/1104)+60)$dBm
$4545 < f \leq 11040$	–90 peak, with maximum power in the [f, f+1 MHz] window of –50 dBm

Table 2. D1 PSD Mask Definition, peak values

[0085] According to some embodiments of the invention U2 (dashed line) and D2 (solid line) spectrum masks may be plotted as shown in Figure 2. Note that, as above, the masks for peak values are defined. The PSD templates, or average PSD values, are 3.5 dB lower than the mask values. Tables 3 and 4 show some values for U2 and D2 (respectively) in accordance with some embodiments of the invention.

Frequency Band f (kHz)	**Equation for the PSD mask (dBm/Hz)**
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f \leq 25.875$	$-92.5 - 22.5 \times \log_2(f/4)$;
$25.875 < f \leq 86.25$	–30.9
$86.25 < f \leq 138.6$	$-34.5 - 95 \times \log_2 (f/86.25)$
$138.6 < f \leq 1221$	–99.5
$1221 < f \leq 1630$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
$1630 < f \leq 11\,040$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of –50 dBm

Table 3. U2 Mask Definition, peak values

Starting Frequency (kHz)	**Starting PSD mask value (dBm/Hz)**
0.000000	-98.000000
3.990000	-98.000000
4.000000	-92.500000
80.000000	-72.500000
120.740000	-47.500000
120.750000	-37.800000
138.000000	-36.800000
276.000000	-33.500000
677.062500	-33.500000
956.000000	-62.000000
1800.000000	-62.000000
2290.000000	-90.000000
3093.000000	-90.000000
4545.000000	-110.000000
12000.000000	-110.000000

Table 4. D2 Mask Definition, peak values

[0086] Similarly, tables 5 and 6 give the breakpoints of U3 and D3 PSD Templates (*average values*) in accordance with some embodiments of the invention. Figure 3

shows U3 (dashed line) and D3 (solid line) according to some embodiments of the invention.

Frequency [KHz]	**Nominal Upstream PSD [dBm/Hz]**
0	-101.5
4	-101.5
4	-96
25.875	-36.30
103.5	-36.30
164.1	-99.5
1221	-99.5
1630	-113.5
12000	-113.5

Table 5. U3 Spectrum PSD Template, average values

Frequency [kHz]	**Nominal Downstream PSD [dBm/Hz]**
0	-101.5
4	-101.5
4	-96
80	-76
138	-47.5
138	-40
276	-37
552	-37
956	-65.5
1800	-65.5
2290	-93.5
3093	-93.5
4545	-113.5
12000	-113.5

Table 6. D3 Spectrum PSD Template, average values

[0087] Smart system scenario detection.

[0088] In this scenario, it is assumed that the Smart LDSL system has the capability either to analyze *a priori* the cross talk/physical layer conditions, or to pick up a mask after testing all of them based on performance and spectral compatibility criteria. Under this feature, all the modems located in the same area will detect the same type of cross talk/impairments. Therefore, the worst case catastrophic scenario based on the use of all the possible masks at any location happens to be a completely unrealistic view for a genuine smart system. This feature was incorporated with success in the already deployed smart enhanced Annex C for Japan.

[0089] Example 1: NON EC Smart LDSL

[0090] Definition

[0091] In this exemplary embodiment, a first smart system makes use of U1, U2, U3 and D1, D3 masks. According to the features of all these masks, no Echo canceller is required by this embodiment of a smart system that will be identified as NON EC Smart LDSL.

[0092] Simulation Results

[0093] Tables 7 and 8 gives the ADSL2 upstream and downstream performance for calibration purposes.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
ADSL2	xDSL 10	1107	1107	596	294	305	570	646	1133
	xDSL 11	884	884	319	120	130	291	361	894
	xDSL 12	846	846	275	**90**	102	248	314	854
	xDSL 13	692	692	142	**48**	**54**	99	163	697
	xDSL 160	969	969	406	141	157	380	452	986
	xDSL 165	925	925	360	116	130	330	404	944
	xDSL 170	881	881	313	**94**	106	287	354	897
	xDSL 175	837	837	269	**78**	**89**	243	306	851
	xDSL 180	798	798	225	**63**	**74**	202	266	805
	xDSL 185	755	755	185	**51**	**60**	162	224	764

Table 7. ADSL2 Upstream Channel performance

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
ADSL2	xDSL 10	298	298	305	328	326	307	162	170
	xDSL 11	0	0	0	0	0	0	0	0
	xDSL 12	0	0	0	0	0	0	0	0
	xDSL 13	0	0	0	0	0	0	0	0
	xDSL 160	300	300	303	323	321	303	88	91
	xDSL 165	201	201	203	224	224	207	43	49
	xDSL 170	125	125	113	141	140	123	8	13
	xDSL 175	59	66	57	74	74	63	0	0
	xDSL 180	0	8	12	17	17	12	0	0
	xDSL 185	0	0	0	0	0	0	0	0

Table 8. ADSL2 Downstream Channel performance

[0094] Tables 9 and 10 display the results of the Modified OJ-074. These results may be taken as references for LDSL.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
M OJ-074	xDSL 10	839	841	488	300	315	458	510	844
	xDSL 11	667	667	312	144	159	283	332	669
	xDSL 12	622	623	270	111	124	242	289	624
	xDSL 13	496	496	157	59	69	136	176	497
	xDSL 160	709	710	353	174	191	324	374	711
	xDSL 165	675	675	319	145	161	291	340	677
	xDSL 170	641	641	287	120	134	259	307	642
	xDSL 175	606	606	255	101	110	227	275	608
	xDSL 180	572	572	224	80	92	198	243	573
	xDSL 185	537	537	195	66	76	169	212	539

Table 9. M OJ-074 Upstream Channel Performance Results

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
M OJ-074	xDSL 10	2396	1659	1784	2023	1991	1616	224	436
	xDSL 11	997	407	431	861	892	358	0	79
	xDSL 12	1202	643	622	974	969	546	0	48
	xDSL 13	855	398	449	696	776	350	0	52
	xDSL 160	2048	1333	1413	1752	1725	1268	150	331
	xDSL 165	1788	1086	1179	1527	1518	1027	92	261
	xDSL 170	1553	875	933	1326	1332	809	53	205
	xDSL 175	1343	754	755	1145	1163	648	25	152
	xDSL 180	1147	633	694	985	1011	579	4	111
	xDSL 185	978	529	608	840	872	500	0	76

Table 10. M OJ-074 Upstream Channel Performance Results

[0095] Tables 11 and 12 give the results of NON EC Smart LDSL system.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
	xDSL 10	839	841	488	310	324	458	510	851
	xDSL 11	667	667	312	179	196	283	332	673
	xDSL 12	622	623	270	146	157	242	289	628
	xDSL 13	496	496	176	102	110	142	176	500
NON EC	xDSL 160	709	710	353	206	219	324	374	716
SMART	xDSL 165	675	675	319	182	195	291	340	681
	xDSL 170	641	641	287	152	168	259	307	646
	xDSL 175	606	606	255	136	145	227	275	611
	xDSL 180	572	572	226	122	130	198	243	577
	xDSL 185	537	537	200	108	116	169	212	542

Table 11. NON EC Smart LDSL Upstream Channel Performance Results

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
	xDSL 10	2615	1711	1946	2148	2169	1679	224	572
	xDSL 11	1060	407	445	902	958	358	**0**	**135**
	xDSL 12	1265	643	634	998	1025	546	**0**	**105**
	xDSL 13	885	398	449	705	816	350	**0**	**79**
NON EC	xDSL 160	2156	1333	1466	1797	1816	1268	**150**	429
SMART	xDSL 165	1885	1086	1222	1572	1604	1027	**92**	349
	xDSL 170	1639	875	967	1370	1413	809	**53**	278
	xDSL 175	1418	754	782	1187	1237	648	**25**	220
	xDSL 180	1213	633	720	1025	1079	579	**4**	**169**
	xDSL 185	1034	529	629	877	932	500	**0**	**126**

Table 12. NON EC Smart LDSL Downstream Channel Performance Results

[0096] Tables 13 and 14 give the selected Upstream and Downstream masks by the smart system. These tables confirm that, for this embodiment, a single mask can't handle all the noise scenarios and all the loops.

		Upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
selection index	xDSL 10	3	3	3	2	2	3	3	3
	xDSL 11	3	3	3	2	2	3	3	3
	xDSL 12	3	3	3	1	2	3	3	3
	xDSL 13	3	3	2	1	1	2	2	3
	xDSL 160	3	3	3	2	2	3	3	3
	xDSL 165	3	3	3	2	2	3	3	3
	xDSL 170	3	3	3	2	2	3	3	3
	xDSL 175	3	3	3	1	1	3	3	3
	xDSL 180	3	3	2	1	1	3	3	3
	xDSL 185	3	3	2	1	1	3	3	3

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

Table 13. NON EC Smart LDSL: Upstream Selection Table

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
selection index	xDSL 10	1	1	1	1	1	1	2	1
	xDSL 11	1	2	1	1	1	2	1	1
	xDSL 12	1	2	1	1	1	2	1	1
	xDSL 13	1	2	2	1	1	2	1	1
	xDSL 160	1	2	1	1	1	2	2	1
	xDSL 165	1	2	1	1	1	2	2	1
	xDSL 170	1	2	1	1	1	2	2	1
	xDSL 175	1	2	1	1	1	2	2	1
	xDSL 180	1	2	1	1	1	2	2	1
	xDSL 185	1	2	1	1	1	2	1	1

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

Table 14. NON EC Smart LDSL: Downstream Selection Table

[0097] Tables 15 and 16 provide the performance improvement inherent to the NON EC Smart LDSL versus M OJ-074. As can be seen from the tables, this embodiment of a smart system performs better than the system disclosed in M OJ-

074. This embodiment of a smart system compensates for the M OJ-074 Upstream channel weaknesses in the presence of SHDSL and HDSL.

upstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
0	0	0	10	9	0	0	7
0	0	0	35	37	0	0	4
0	0	0	35	33	0	0	4
0	0	19	43	41	6	0	3
0	0	0	32	28	0	0	5
0	0	0	37	34	0	0	4
0	0	0	32	34	0	0	4
0	0	0	35	35	0	0	3
0	0	2	42	38	0	0	4
0	0	5	42	40	0	0	3

Table 15. (NON EC SMART LDSL US rate – M OJ074 US rate)

downstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
219	52	162	125	178	63	0	136
63	0	14	41	66	0	0	56
63	0	12	24	56	0	0	57
30	0	0	9	40	0	0	27
108	0	53	45	91	0	0	98
97	0	43	45	86	0	0	88
86	0	34	44	81	0	0	73
75	0	27	42	74	0	0	68
66	0	26	40	68	0	0	58
56	0	21	37	60	0	0	50

Table 16. (NON EC SMART LDSL DS rate – M OJ074 DS rate)

[0098] Figures 4-19 show bar chart performance plots of ADSL2, non-EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases.

[0099] EC Smart LDSL system

[00100] Definition

[0100] As described above, a first exemplary smart system may make use of U1, U2, U3 and D1, D2, D3. In accordance with the features of all these masks, an Echo

canceller may be advantageous when D2 is used. A second exemplary smart system may be identified as the EC Smart LDSL. For this embodiment, the Smart LDSL system may have the capability to analyze *a priori* the cross talk/physical layer conditions for all the Smart LDSL modems located in the same area. In addition the system may detect the same type of cross talks/impairments and, therefore, the worst case self NEXT due to the Downstream mask D2 may only apply when this mask is used.

[0101] EC Smart LDSL: Simulation results

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	839	841	488	310	324	458	456	423
	xDSL 11	667	667	312	179	196	283	280	253
	xDSL 12	622	623	270	146	157	242	239	214
	xDSL 13	496	496	176	102	110	142	135	130
	xDSL 160	709	710	353	206	219	324	321	291
	xDSL 165	675	675	319	182	195	291	288	259
	xDSL 170	641	641	287	152	168	259	256	229
	xDSL 175	606	606	255	136	145	227	225	200
	xDSL 180	572	572	226	122	130	198	195	168
	xDSL 185	537	537	200	108	116	169	166	139

Table 17. EC Smart LDSL Upstream Channel Performance Results

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	2615	1711	1946	2148	2169	1679	381	719
	xDSL 11	1060	407	445	902	958	358	**54**	193
	xDSL 12	1265	643	634	998	1025	546	**38**	**140**
	xDSL 13	885	398	449	705	816	350	**18**	**80**
	xDSL 160	2156	1333	1466	1797	1816	1268	216	476
	xDSL 165	1885	1086	1222	1572	1604	1027	**140**	388
	xDSL 170	1639	875	967	1370	1413	809	**86**	308
	xDSL 175	1418	754	782	1187	1237	648	**62**	237
	xDSL 180	1213	633	720	1025	1079	579	**28**	**181**
	xDSL 185	1034	529	629	877	932	500	**20**	**127**

Table 18. EC Smart LDSL Downstream Channel Performance Results

		Upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	3	3	3	2	2	3	3	3
	xDSL 11	3	3	3	2	2	3	3	3
	xDSL 12	3	3	3	1	2	3	3	3
	xDSL 13	3	3	2	1	1	2	2	1
	xDSL 160	3	3	3	2	2	3	3	3
	xDSL 165	3	3	3	2	2	3	3	3
	xDSL 170	3	3	3	2	2	3	3	3
	xDSL 175	3	3	3	1	1	3	3	3
	xDSL 180	3	3	2	1	1	3	3	2
	xDSL 185	3	3	2	1	1	3	3	2

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

Table 19. EC Smart LDSL: Upstream Selection Table

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	2	2	2	2	2	2	1	1
	xDSL 11	2	3	2	2	2	3	1	1
	xDSL 12	2	3	2	2	2	3	1	1
	xDSL 13	2	3	3	2	2	3	1	1
	xDSL 160	2	3	2	2	2	3	1	1
	xDSL 165	2	3	2	2	2	3	1	1
	xDSL 170	2	3	2	2	2	3	1	1
	xDSL 175	2	3	2	2	2	3	1	1
	xDSL 180	2	3	2	2	2	3	1	1
	xDSL 185	2	3	2	2	2	3	1	1

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

Table 20. EC Smart LDSL: Downstream Selection Table

upstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
0	0	0	10	9	0	-54	-421
0	0	0	35	37	0	-52	-416
0	0	0	35	33	0	-50	-410
0	0	19	43	41	6	-41	-367
0	0	0	32	28	0	-53	-420
0	0	0	37	34	0	-52	-418
0	0	0	32	34	0	-51	-413
0	0	0	35	35	0	-50	-408
0	0	2	42	38	0	-48	-405
0	0	5	42	40	0	-46	-400

Table 21. (EC SMART LDSL US rate – M OJ074 US rate)

downstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
219	52	162	125	178	63	157	283
63	0	14	41	66	0	54	114
63	0	12	24	56	0	38	92
30	0	0	9	40	0	18	28
108	0	53	45	91	0	66	145
97	0	43	45	86	0	48	127
86	0	34	44	81	0	33	103
75	0	27	42	74	0	37	85
66	0	26	40	68	0	24	70
56	0	21	37	60	0	20	51

Table 22. (EC SMART LDSL DS rate – M OJ074 DS rate)

[0102] Figures 20-35 show bar chart performance plots of ADSL2, EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases.

[0103] Smart DSL Implementation based on ITU-T Recommendation G.992.3

[00101] Two steps

[0104] Deciding to access one of the mask amongst all the possible choices offered by a smart DSL platform may be facilitated by using a two step process in the following order:

[0105] (1) Masks Choice based on Performance/Physical layer status criterion: Smart functionality; and (2) Protocol to activate one particular mask based on CP/CO capabilities.

[0106] Step (1): Mask Choice based on Performance/Physical layer Status: Smart Functionality.

[0107] Figure 36 displays the org chart that describes the two selection modes inherent to smart DSL: manual or automatic.

[0108] The automatic selection may be completed in two different ways: by making use of the Line Probing capabilities of G.992.3 (LP Option) or by trying different masks up to the training and choosing at the end the best (Many Tests Option). Figure 37 gives the state diagram of the two approaches to automatically select a pair of mask for a smart DSL platform.

[0109] The LP option needs to complete the right loop of operations in figure 37 one time only. The Many tests option requires to complete the left loop of operations in figure 37 as many times as the number of available possibilities.

[0110] Step 2: Protocol to activate one mask based on CO / CP capabilities.

[00102] This section discloses three protocol examples to activate one mask based on CO/CP capabilities.

[0111] Option 1: CP decides

[0112] Figure 38 describes the "CP decides" which mask is to be used sequence, based on G.992.3. CLR and CL allow CP and CO to signify their list of capabilities.

[0113] Option 2: CO decides

[0114] Figure 39 describes the "CO decides" which mask is to be used sequence, based on G.992.3, after being requested by the CP to do so. CLR and CL allow CP and CO to signify their list of capabilities.

[0115] Option 3: CP is overruled by CO

[0116] Figure 40 describes the "CO overrules CP" about which mask is to be used sequence, based on G.992.3, after CP has mentioned which mask is to be used . CLR and CL allow CP and CO to signify their list of capabilities.

[0117] LDSL Wide and Narrow Downstream Masks

[0118] The following evaluates the spectral compatibility of two LDSL modes based on two different downstream masks identified herein as LDSL Wide and Narrow and a known same G.992.1 upstream mask. Spectral compatibility is evaluated according to the 2003 Soumusho updated rules. Other compatibility rules may also be used.

[0119] Some LDSL Wide and Narrow modes of operation are spectrally compatible with protected systems in Japan, known as TCM-ISDN, Annex A G.992.1 and G.992.2, Annex C DBM G.992.1 and G.992.2, Annex C FBM G.992.1 and G.992.2.

[0120] As noted above, both LDSL modes of operation may make use of a single upstream mask preferably identical to the G.992.1 PSD (power spectral density) Upstream Mask. The LDSL Wide and Narrow modes may be based on two different downstream masks identified herein as the LDSL Downstream Wide Mask and LDSL Downstream Narrow Mask, respectively.

[0121] Note that the values provided in the following Figures 41 and 42 and in Tables 35-40 are approximate, or mean values, and may have a variance of up to 10%.

[0122] Figure 41 displays the LDSL Downstream Wide Mask and the G.992.1 Upstream Nominal Mask. Table 23 provides exemplary LDSL Downstream Wide Mask peak values. Note that the values provided in Table 23 are approximate, or mean values, and may have a variance of 10% or more.

[0123] Figure 42 displays the LDSL Downstream Narrow Mask and the G.992.1 Upstream Nominal Mask. Table 24 provides exemplary LDSL Downstream Narrow Mask peak values.

[0124] LDSL Wide Mode, as defined herein, combines the use of the G.992.1 Upstream Mask and the LDSL Wide Downstream Mask defined above. Table 25 provides the spectral compatibility impact of LDSL Wide Mode with upstream channels of protected systems. Table 25 further gives also the reference numbers. It may be derived from Table 25 that LDSL Wide Mode is always spectrally compatible with the upstream channels of protected systems.

[0125] Table 26 provides the spectral compatibility impact of the LDSL Wide Mode with downstream channels of protected systems. Table 26 also gives the reference numbers. It may be derived from Table 26 that LDSL Wide Mode is always spectrally compatible with the downstream channels of protected systems.

[0126] LDSL Narrow Mode, as defined herein, combines the G.992.1 Upstream Mask and the LDSL Narrow Mask described above. Table 27 provides the spectral compatibility impact of the LDSL Narrow Mode with upstream channels of protected systems. Table 27 also provides the reference numbers. It may be derived from Table 27 that the LDSL Narrow Mode is always spectrally compatible with the upstream channels of protected systems.

[0127] Table 28 provides the spectral compatibility impact of the LDSL Narrow Mode with downstream channels of protected systems. Table 28 also provides the reference numbers. It may be derived from Table 28 that the LDSL Narrow Mode is always spectrally compatible with the downstream channels of protected systems.

[0128] Based on the above, it may be shown that both LDSL Wide and Narrow modes of operation are spectrally compatible with protected systems in Japan.

Table 23. LDSL Downstream Wide Mask Peak Values

Frequency f (KHz)	PSD (dBm/Hz) Peak values
$0<f\leq 4$	-97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4<f\leq 5$	-92.5+18.64log2(*f*/4)
5<f≤5.25	-86.5
5.25<f≤16	-86.5+15.25log2(f/5.25)
$16<f\leq 32$	-62+25.5log2(*f*/16)
$32<f\leq 138$	-36.5
$138<f\leq 323.4375$	-31.8
$323.4375<f\leq 517.5$	-31.8- 0.0371× (f-323.4375)
$258.75<f\leq 1800$	max(-39 - 23.27 × $\log_2$ (*f*/517.5),-65)
$1800<f\leq 2290$	-65 - 72 × $\log_2$ (*f*/1800)
$2290<f\leq 3093$	–90
$3093<f\leq 4545$	–90 peak, with max power in the [*f*, *f* + 1 MHz] window of (–36.5 – 36 × $\log_2$ (*f*/1104) + 60) dBm
$4545<f\leq 11\,040$	–90 peak, with max power in the [*f*, *f* + 1 MHz] window of –50 dBm

NOTE 1 –	All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2 –	The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3 –	Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
NOTE 4 –	The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5 –	The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6 –	All PSD and power measurements shall be made at the U-C interface (see Figure 5-4 and Figure 5-5); the signals delivered to the PSTN are specified in Annex E.
NOTE 7 –	frequencies are in kHz in the formulas.

Table 24. LDSL Downstream Wide Mask Peak Values

Frequency f (KHz)	PSD (dBm/Hz) Peak values
$0<f\leq 4$	-97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4<f\leq 5$	-92.5+18.64log2(f/4)
5<f≤5.25	-86.5
5.25<f≤16	-86.5+15.25log2(f/5.25)
$16<f\leq 32$	-62+25.5log2(f/16)
$32<f\leq 73.3125$	-34
$73.3125<f\leq 138$	-40.9
$138<f\leq 237.1875$	-28.9
$237.1875<f\leq 258.75$	-29.5
$258.75<f\leq 1800$	$\max(-29.5 - 23.27 \times \log_2(f/258.75),-65)$
$1800<f\leq 2290$	$-65 - 72 \times \log_2(f/1800)$
$2290<f\leq 3093$	–90
$3093<f\leq 4545$	–90 peak, with max power in the $[f, f+1$ MHz$]$ window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm
$4545<f\leq 11\,040$	–90 peak, with max power in the $[f, f+1$ MHz$]$ window of –50 dBm
NOTE 1 –	All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.
NOTE 2 –	The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
NOTE 3 –	Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
NOTE 4 –	The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency.
NOTE 5 –	The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.
NOTE 6 –	All PSD and power measurements shall be made at the U-C interface (see Figure 5-4 and

	Figure 5-5); the signals delivered to the PSTN are specified in Annex E.
NOTE 7 –	frequencies are in kHz in the formulas.

Table 25. LDSL Wide Mode Upstream Spectral Compatibility vs Reference numbers

	TCM_ISDN		A		A_lite		C_DBM		C_DBM_lite		C_FBM		C_FBM_lite	
km	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual
0.5	61	68	832	832	832	832	832	832	832	832	288	288	288	288
0.75	58	66	832	832	832	832	832	832	832	832	288	288	288	288
1.0	55	65	832	832	832	832	832	832	832	832	288	288	288	288
1.25	52	64	800	832	800	832	800	832	800	832	288	288	288	288
1.5	49	63	768	832	768	832	800	832	800	832	288	288	288	288
1.75	46	63	736	800	736	800	768	800	768	800	288	288	288	288
2.0	43	62	704	768	704	768	736	800	736	800	288	288	288	288
2.25	41	62	640	736	640	736	704	768	704	768	288	288	288	288
2.5	38	61	576	672	576	672	672	736	672	736	288	288	288	288
2.75	35	61	512	608	512	608	640	672	640	672	288	288	288	288
3.0	32	60	448	544	448	544	576	640	576	640	288	288	288	288
3.25	29	60	352	480	352	480	512	608	512	608	256	288	256	288
3.5	26	60	288	384	288	384	480	544	480	544	256	288	256	288
3.75	23	59	224	288	224	288	448	480	448	480	256	288	256	288
4.0	20	59	192	224	192	224	416	448	416	448	256	288	256	288
4.25	17	58	160	160	160	160	416	416	416	416	224	288	224	288
4.5	14	57	128	128	128	128	384	384	384	384	224	288	224	288
4.75	11	56	96	96	96	96	352	352	352	352	224	288	224	288
5.0	8	55	64	64	64	64	352	352	352	352	192	288	192	288

Table 26. LDSL Wide Mode Downstream Spectral Compatibility vs Reference numbers

	TCM_ISDN		A		A_lite		C_DBM		C_DBM_lite		C_FBM		C_FBM_lite	
km	ref	actual	ref	actual	ref	actual	ref	km	ref	actual	ref	actual	ref	actual
0.5	60	65	7104	7104	3008	3008	7104	7104	3008	3008	2624	2624	1088	1088
0.75	57	63	6784	7104	2784	3008	6912	7104	2848	3008	2624	2624	1088	1088
1.0	55	62	5952	7104	2400	3008	6368	7104	2624	3008	2624	2624	1088	1088
1.25	52	61	4896	7104	2016	3008	5696	7104	2368	3008	2624	2624	1088	1088
1.5	50	60	3840	7072	1632	2976	5024	7072	2144	2976	2624	2624	1088	1088
1.75	47	59	2496	7072	1184	2976	4192	7072	1856	2976	2624	2624	1088	1088
2.0	45	59	1696	7040	736	2944	3680	7072	1568	2976	2528	2624	1088	1088
2.25	43	58	1088	6784	448	2944	3296	6880	1376	2944	2464	2624	1088	1088
2.5	40	58	704	6176	224	2880	3008	6464	1248	2912	2368	2560	1088	1088
2.75	38	57	480	5344	128	2784	2720	5792	1184	2880	2240	2400	1088	1088
3.0	35	57	320	4384	96	2688	2368	4928	1152	2816	1984	2112	1056	1056
3.25	32	57	224	3520	64	2528	1984	4096	1152	2720	1696	1760	1024	1024
3.5	30	56	128	2848	32	2304	1632	3328	1120	2560	1408	1440	992	992
3.75	27	56	64	2304	0	2048	1344	2720	1056	2336	1152	1216	928	960
4.0	25	56	32	1792	0	1728	1088	2208	960	2048	928	992	832	896
4.25	22	55	0	1376	0	1376	928	1728	896	1696	768	832	736	800
4.5	20	55	0	992	0	992	768	1344	768	1344	576	704	576	704
4.75	17	54	0	672	0	672	608	1024	608	1024	448	576	448	576
5.0	15	53	0	416	0	416	512	768	512	768	320	480	320	480

Table 27. LDSL Narrow Mode Upstream Spectral Compatibility vs Reference numbers

	TCM_ISDN		A		A_lite		C_DBM		C_DBM_lite		C_FBM		C_FBM_lite	
km	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual	ref	actual
0.5	61	68	832	832	832	832	832	832	832	832	288	288	288	288
0.75	58	66	832	832	832	832	832	832	832	832	288	288	288	288
1.0	55	65	832	832	832	832	832	832	832	832	288	288	288	288
1.25	52	64	800	832	800	832	800	832	800	832	288	288	288	288
1.5	49	63	768	832	768	832	800	832	800	832	288	288	288	288
1.758	46	63	736	832	736	832	768	832	768	832	288	288	288	288
2.0	43	62	704	832	704	832	736	832	736	832	288	288	288	288
2.25	41	62	640	800	640	800	704	800	704	800	288	288	288	288
2.5	38	61	576	736	576	736	672	768	672	768	288	288	288	288
2.75	35	61	512	672	512	672	640	736	640	736	288	288	288	288
3.0	32	60	448	608	448	608	576	672	576	672	288	288	288	288
3.25	29	60	352	512	352	512	512	640	512	640	256	288	256	288
3.5	26	60	288	448	288	448	480	576	480	576	256	288	256	288
3.75	23	59	224	384	224	384	448	544	448	544	256	288	256	288
4.0	20	59	192	288	192	288	416	480	416	480	256	288	256	288
4.25	17	58	160	192	160	192	416	416	416	416	224	288	224	288
4.5	14	57	128	128	128	128	384	384	384	384	224	288	224	288
4.75	11	56	96	96	96	96	352	352	352	352	224	288	224	288
5.0	8	55	64	64	64	64	352	320	352	320	192	288	192	288

Table 28. LDSL Narrow Mode Downstream Spectral Compatibility vs Reference numbers

	TCM_ISDN		A		A_lite		C_DBM		C_DBM_lite		C_FBM		C_FBM_lite	
km	ref	actual	ref	actual	ref	actual	ref	km	ref	actual	ref	actual	ref	actual
0.5	60	63	7104	7104	3008	3008	7104	7104	3008	3008	2624	2624	1088	1088
0.75	57	61	6784	7104	2784	3008	6912	7104	2848	3008	2624	2624	1088	1088
1.0	55	60	5952	7104	2400	3008	6368	7104	2624	3008	2624	2624	1088	1088
1.25	52	59	4896	7104	2016	3008	5696	7104	2368	3008	2624	2624	1088	1088
1.5	50	58	3840	7072	1632	2976	5024	7072	2144	2976	2624	2624	1088	1088
1.758	47	57	2496	7072	1184	2976	4192	7072	1856	2976	2624	2624	1088	1088
2.0	45	57	1696	7040	736	2944	3680	7072	1568	2976	2528	2624	1088	1088
2.25	43	56	1088	6784	448	2912	3296	6880	1376	2944	2464	2624	1088	1088
2.5	40	56	704	6176	224	2880	3008	6464	1248	2912	2368	2560	1088	1088
2.75	38	55	480	5376	128	2784	2720	5824	1184	2880	2240	2400	1088	1088
3.0	35	55	320	4416	96	2752	2368	4960	1152	2848	1984	2144	1056	1088
3.25	32	55	224	3616	64	2624	1984	4128	1152	2784	1696	1824	1024	1088
3.5	30	54	128	2944	32	2432	1632	3392	1120	2624	1408	1504	992	1056
3.75	27	54	64	2368	0	2144	1344	2784	1056	2400	1152	1248	928	1024
4.0	25	54	32	1856	0	1824	1088	2240	960	2080	928	1056	832	928
4.25	22	53	0	1408	0	1408	928	1760	896	1728	768	864	736	832
4.5	20	53	0	992	0	992	768	1344	768	1344	576	704	576	704
4.75	17	52	0	672	0	672	608	992	608	992	448	576	448	576
5.0	15	52	0	416	0	416	512	736	512	736	320	480	320	480

[0129] FDM Quad Spectrum Mode.

[0130] Described in the following is a FDM Quad Spectrum mode for high speed ADSL and an evaluation of its spectral compatibility according to the 2003 revised TTC-Soumusho spectral compatibility rules. The FDM Quad Spectrum mode, in one embodiment, combines an extended downstream bandwidth PSD (from approximately 138 KHz up to approximately 3.75 MHz) with the G.992.5 upstream PSD (with steep side lobes of approximately -95 dB per octave slope). The FDM Quad Spectrum downstream channel total power preferably is equal to approximately 20 dBm.

[0131] Note that the values provided in the following Figures 43 and 44 and in Tables 41-45 are approximate, or mean values, and may have a variance of up to 10%.

[0132] Figure 43 and Table 29 provide an exemplary embodiment of the FDM Quad Spectrum Mask features based on peak values.

[0133] Figure 44 and Table 30 provide the G.992.5 Upstream Mask features based on peak values.

[0134] Table 31 provides the spectral compatibility reference performance of protected systems, according to the Revised 2003 Soumusho-TTC rules.

[0135] Table 32 provides the performance of protected systems in the presence of five FDM Quad Spectrum system disturbers.

[0136] Table 33 gives the delta between the reference performance (Table 31) and the performance in the presence of five FDM quad spectrum systems (Table 32). To be spectrally compatible, these numbers may be negative in the presence of a new system. The performance of the protected systems may be greater or equal to the reference performance.

[0137] The FDM Quad Spectrum mode is spectrally compatible with protected systems in Japan identified as TCM-ISDN, Annex A G.992.1 and G.992.2, Annex C DBM G.992.1 and G.992.2, Annex C FBM G.992.1 and G.992.2.

Table 29 Quad Spectrum Mask definition, Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<80	"-92.5 + 4.63.log2.(f/4)"
80<f<138	"-72.5 + 36.log2.(f/80)"
138<f<1104	-37.9
1104<f<1622	"-37.9 - 15.5.log2.(f/1104)"
1622<f<3750	"-46.5 - 2.9.log2.(f/1622)"
3750	-76.5
f=3925 & f>3925	-101.5

Table 30. G.992.5 Upstream Mask Definition, Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.5.log2.(f/4)"
25.875<f<138	-34.5
138<f<f_int	"-34.5 - 95.log2.(f/138)"
f_int<f<686	10log10(0.05683*f^(1.5))
f>686	-100

Table 31. Spectral Compatibility Reference Performance, Protected Systems

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	6784	832	2944	832	6912	832	2592	288	2944	832	1088	288
1	144	144	5952	832	2624	832	6368	832	2528	288	2752	832	1088	288
1.25	144	144	4896	800	2272	800	5696	800	2496	288	2528	800	1088	288
1.5	144	144	3840	768	1824	768	5024	800	2432	288	2272	800	1088	288
1.75	144	144	2496	736	1440	736	4192	768	2400	288	2016	768	1088	288
2	144	144	1696	704	960	704	3680	736	2336	288	1696	736	1088	288
2.25	144	144	1088	640	640	640	3296	704	2240	288	1504	704	1088	288
2.5	144	144	704	576	352	576	3008	672	2080	288	1312	672	1056	288
2.75	144	144	480	512	160	512	2720	640	1856	288	1216	640	1056	288
3	144	144	320	448	96	448	2368	576	1536	288	1184	576	1024	288
3.25	144	144	224	352	64	352	1984	512	1280	288	1152	512	992	288
3.5	144	0	128	288	32	288	1632	480	1056	288	1120	480	928	288
3.75	0	0	64	224	32	224	1344	448	832	256	1088	448	832	256
4	0	0	32	192	0	192	1088	416	640	256	1024	416	704	256
4.25	0	0	0	160	0	160	928	416	480	256	928	416	576	256
4.5	0	0	0	128	0	128	768	384	352	224	832	384	416	224
4.75	0	0	0	96	0	96	608	352	224	224	704	352	288	224
5	0	0	0	64	0	64	416	352	128	224	544	352	192	224

Table 32. Protected Systems performance with 5 FDM Quad Spectrum Systems (1 Intra-Quad,4 Inter-Quad)

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1	144	144	7008	832	3008	832	7008	832	2592	288	3008	832	1088	288
1.25	144	144	6912	832	3008	832	6912	832	2560	288	3008	832	1088	288
1.5	144	144	6848	832	3008	832	6848	832	2528	288	3008	832	1088	288
1.75	144	144	6752	832	2976	832	6752	832	2496	288	2976	832	1088	288
2	144	144	6624	832	2976	832	6624	832	2432	288	2976	832	1088	288
2.25	144	144	6496	832	2976	832	6496	832	2400	288	2976	832	1088	288
2.5	144	144	6240	832	2976	832	6240	832	2304	288	2976	832	1088	288
2.75	144	144	5856	800	2944	800	5856	800	2144	288	2944	800	1088	288
3	144	144	5248	800	2944	800	5248	800	1920	288	2944	800	1088	288
3.25	144	144	4416	800	2912	800	4416	800	1632	288	2912	800	1056	288
3.5	144	144	3712	768	2816	768	3712	768	1376	288	2816	768	1024	288
3.75	0	0	3104	736	2688	736	3104	736	1120	256	2688	736	992	256
4	0	0	2560	736	2464	736	2560	736	928	256	2464	736	896	256
4.25	0	0	2080	704	2240	704	2080	704	768	256	2240	704	800	256
4.5	0	0	1696	672	1920	672	1696	672	608	224	1920	672	704	224
4.75	0	0	1344	640	1536	640	1344	640	480	224	1536	640	544	224
5	0	0	1024	608	1184	608	1024	608	352	224	1184	608	448	224

Table 33. Reference Performance minus Performance with 5 FDM Quad Spectrum

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist		(FDM)			DBM				FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	-320	0	-64	0	-192	0	-32	0	-64	0	0	0
1	0	0	-1056	0	-384	0	-640	0	-64	0	-256	0	0	0
1.25	0	0	-2016	-32	-736	-32	-1216	-32	-64	0	-480	-32	0	0
1.5	0	0	-3008	-64	-1184	-64	-1824	-32	-96	0	-736	-32	0	0
1.75	0	0	-4256	-96	-1536	-96	-2560	-64	-96	0	-960	-64	0	0
2	0	0	-4928	-128	-2016	-128	-2944	-96	-96	0	-1280	-96	0	0
2.25	0	0	-5408	-192	-2336	-192	-3200	-128	-160	0	-1472	-128	0	0
2.5	0	0	-5536	-256	-2624	-256	-3232	-160	-224	0	-1664	-160	-32	0
2.75	0	0	-5376	-288	-2784	-288	-3136	-160	-288	0	-1728	-160	-32	0
3	0	0	-4928	-352	-2848	-352	-2880	-224	-384	0	-1760	-224	-64	0
3.25	0	0	-4192	-448	-2848	-448	-2432	-288	-352	0	-1760	-288	-64	0
3.5	0	-144	-3584	-480	-2784	-480	-2080	-288	-320	0	-1696	-288	-96	0
3.75	0	0	-3040	-512	-2656	-512	-1760	-288	-288	0	-1600	-288	-160	0
4	0	0	-2528	-544	-2464	-544	-1472	-320	-288	0	-1440	-320	-192	0
4.25	0	0	-2080	-544	-2240	-544	-1152	-288	-288	0	-1312	-288	-224	0
4.5	0	0	-1696	-544	-1920	-544	-928	-288	-256	0	-1088	-288	-288	0
4.75	0	0	-1344	-544	-1536	-544	-736	-288	-256	0	-832	-288	-256	0
5	0	0	-1024	-544	-1184	-544	-608	-256	-224	0	-640	-256	-256	0

[0138] Extended Upstream OL Overlap Mode

[0139] Described in the following is the spectral compatibility of a high speed system that combines an extended upstream channel up to approximately 276 KHz and an Overlap OL Quad Spectrum downstream channel that starts at approximately 25.875 KHz. Based on the results described below and according to the 2003 refined Soumusho Spectral compatibility rules, in some embodiments it is preferable to deploy the Extended Upstream Overlap System in the same quad as protected systems up to approximately 3.25 km.

[0140] Note that the values provided in the following Figures 45 and 46 and in Tables 46-50 are approximate, or mean values, and may have a variance of up to 10%.

[0141] Figure 45 and Table 34 provided exemplary features of the Extended Overlap Quad Spectrum Downstream Mask.

[0142] Figure 46 and Table 35 provide exemplary features of the Extended Overlap Quad Spectrum Upstream Mask.

[0143] Table 36 provides the spectral compatibility reference performance of protected systems, according to the Revised 2003 Soumusho-TTC rules.

[0144] Table 37 provides the performance of protected systems in the presence of five Extended Overlap upstream systems as disturbers (1 Intra-Quad plus 4 Inter-Quad).

[0145] Table 38 describes the difference between reference performance of protected systems and their performance in the presence of five Extended Overlap upstream systems as overlap systems disturbers. According to Table 38, the Extended Upstream system has little or no impact with Annex C DBM and TCM-ISDN systems up to approximately 3.25 km.

Table 34. Extended Overlap Quad Spectrum Downstream Mask Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.log2.(f/4)"
25.875<f<1104	-38.3
1104<f<1622	"-38.3 - 14.75.log2.(f/1104)"
1622<f<3750	"-46.5 - 2.9.log2.(f/1622)"
f=3750	-76.5
f>3925	-101.5

Table 35. Extended Overlap Quad Spectrum Upstream Mask, Peak values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.5.log2.(f/4)"
25.875<f<138	-34.5
138<f<276	"-34.5 - 26.log2.(f/138)"
276<f<f_int	"-60.5 - 95.log2.(f/276)"
f_int<f<686	10log10(0.05683*f^(1.5))

Table 36. Protected Systems Reference table

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	6784	832	2944	832	6912	832	2592	288	2944	832	1088	288
1	144	144	5952	832	2624	832	6368	832	2528	288	2752	832	1088	288
1.25	144	144	4896	800	2272	800	5696	800	2496	288	2528	800	1088	288
1.5	144	144	3840	768	1824	768	5024	800	2432	288	2272	800	1088	288
1.75	144	144	2496	736	1440	736	4192	768	2400	288	2016	768	1088	288
2	144	144	1696	704	960	704	3680	736	2336	288	1696	736	1088	288
2.25	144	144	1088	640	640	640	3296	704	2240	288	1504	704	1088	288
2.5	144	144	704	576	352	576	3008	672	2080	288	1312	672	1056	288
2.75	144	144	480	512	160	512	2720	640	1856	288	1216	640	1056	288
3	144	144	320	448	96	448	2368	576	1536	288	1184	576	1024	288
3.25	144	144	224	352	64	352	1984	512	1280	288	1152	512	992	288
3.5	144	0	128	288	32	288	1632	480	1056	288	1120	480	928	288
3.75	0	0	64	224	32	224	1344	448	832	256	1088	448	832	256
4	0	0	32	192	0	192	1088	416	640	256	1024	416	704	256
4.25	0	0	0	160	0	160	928	416	480	256	928	416	576	256
4.5	0	0	0	128	0	128	768	384	352	224	832	384	416	224
4.75	0	0	0	96	0	96	608	352	224	224	704	352	288	224
5	0	0	0	64	0	64	416	352	128	224	544	352	192	224

Table 37. Extended Overlap Upstream System Spectral Compatibility Impact.

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1	144	144	7072	832	3008	832	7072	832	2592	288	3008	832	1088	288
1.25	144	144	6944	832	3008	832	6944	832	2560	288	3008	832	1088	288
1.5	144	144	6848	832	2976	832	6848	832	2528	288	2976	832	1088	288
1.75	144	144	6752	832	2976	832	6752	832	2496	288	2976	832	1088	288
2	144	144	6592	800	2912	800	6592	800	2432	288	2912	800	1088	288
2.25	144	144	6368	768	2848	768	6368	768	2336	288	2848	768	1056	288
2.5	144	144	6016	704	2752	704	6016	704	2208	256	2752	704	1024	256
2.75	144	144	5504	672	2624	672	5504	672	2016	224	2624	672	960	224
3	144	144	4768	608	2496	608	4768	608	1760	224	2496	608	928	224
3.25	144	144	3776	512	2368	512	3776	512	1376	192	2368	512	864	192
3.5	0	0	2944	448	2144	448	2944	448	1088	160	2144	448	768	160
3.75	0	0	2208	352	1856	352	2208	352	800	128	1856	352	672	128
4	0	0	1568	288	1536	288	1568	288	576	96	1536	288	544	96
4.25	0	0	1088	224	1216	224	1088	224	384	64	1216	224	448	64
4.5	0	0	704	160	896	160	704	160	256	32	896	160	320	32
4.75	0	0	416	96	576	96	416	96	128	32	576	96	192	32
5	0	0	192	64	320	64	192	64	64	32	320	64	96	32

Table 38. Reference Performance minus Performance with Extended Overlap Upstream System

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	-320	0	-64	0	-192	0	-32	0	-64	0	0	0
1	0	0	-1120	0	-384	0	-704	0	-64	0	-256	0	0	0
1.25	0	0	-2048	-32	-736	-32	-1248	-32	-64	0	-480	-32	0	0
1.5	0	0	-3008	-64	-1152	-64	-1824	-32	-96	0	-704	-32	0	0
1.75	0	0	-4256	-96	-1536	-96	-2560	-64	-96	0	-960	-64	0	0
2	0	0	-4896	-96	-1952	-96	-2912	-64	-96	0	-1216	-64	0	0
2.25	0	0	-5280	-128	-2208	-128	-3072	-64	-96	0	-1344	-64	32	0
2.5	0	0	-5312	-128	-2400	-128	-3008	-32	-128	32	-1440	-32	32	32
2.75	0	0	-5024	-160	-2464	-160	-2784	-32	-160	64	-1408	-32	96	64
3	0	0	-4448	-160	-2400	-160	-2400	-32	-224	64	-1312	-32	96	64
3.25	0	0	-3552	-160	-2304	-160	-1792	0	-96	96	-1216	0	128	96
3.5	144	0	-2816	-160	-2112	-160	-1312	32	-32	128	-1024	32	160	128
3.75	0	0	-2144	-128	-1824	-128	-864	96	32	128	-768	96	160	128
4	0	0	-1536	-96	-1536	-96	-480	128	64	160	-512	128	160	160
4.25	0	0	-1088	-64	-1216	-64	-160	192	96	192	-288	192	128	192
4.5	0	0	-704	-32	-896	-32	64	224	96	192	-64	224	96	192
4.75	0	0	-416	0	-576	0	192	256	96	192	128	256	96	192
5	0	0	-192	0	-320	0	224	288	64	192	224	288	96	192

[0146] Extended Upstream Reduced Overlap (ROL) Spectrum Mode

[0147] Described in the following is an Extended Upstream Reduced Overlap (ROL) system that combines an extended upstream channel up to approximately 276 KHz and a Reduced Overlap ROL Quad Spectrum downstream channel that starts at approximately 138 KHz.

[0148] Note that the values provided in the following Figures 47 and 48 and in Tables 51-54 are approximate, or mean values, and may have a variance of up to 10%.

[0149] Figure 47 and Table 39 provides exemplary features of one embodiment of the Reduced Overlap Quad Spectrum Downstream Mask.

[0150] Figure 48 and Table 40 provides exemplary features of one embodiment of the Reduced Overlap Quad Spectrum Downstream Mask.

[0151] Table 41 provides the performance of protected systems in the presence of five extended Upstream ROL systems as disturbers (1 Intra-Quad plus 4 Inter-Quad).

[0152] Table 42 describes the difference between reference performance of protected systems and their performance in the presence of five Extended Upstream ROL system disturbers. According to Table 42, Extended Upstream ROL System has little or no impact with TCM-ISDN systems up to approximately 3.25 km.

Table 39. Quad Spectrum Reduced Overlap Downstream Mask Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<80	"-92.5 + 4.63.log2.(f/4)"
80<f<138	"-72.5 + 36.log2.(f/80)"
138<f<1104	-37.9
1104<f<1622	"-37.9 - 15.5.log2.(f/1104)"
1622<f<3750	"-46.5 - 2.9.log2.(f/1622)"
3750	-76.5
f=3925 & f>3925	-101.5

Table 40. Extended Upstream Mask, Peak values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.5.log2.(f/4)"
25.875<f<138	-34.5
138<f<276	"-34.5 - 26.log2.(f/138)"
276<f<f_int	"-60.5 - 95.log2.(f/276)"
f_int<f<686	10log10(0.05683*f^(1.5))
f>686	-100

Table 41. Extended Upstream ROL System Spectral Compatibility Impact.

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.
Dist		(FDM)				DBM			FBM		DBM
	DS	US	DS	US	DS	US	DS	US	DS	US	DS
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008
0.75	144	144	7104	832	3008	832	7104	832	2624	288	3008
1	144	144	7008	832	3008	832	7008	832	2592	288	3008
1.25	144	144	6912	832	3008	832	6912	832	2560	288	3008
1.5	144	144	6816	832	2976	832	6816	832	2528	288	2976
1.75	144	144	6720	832	2976	832	6720	832	2464	288	2976
2	144	144	6528	832	2912	832	6528	832	2400	288	2912
2.25	144	144	6304	832	2848	832	6304	832	2336	288	2848
2.5	144	144	5984	832	2752	832	5984	832	2208	288	2752
2.75	144	144	5472	800	2624	800	5472	800	2016	288	2624
3	144	144	4736	800	2496	800	4736	800	1728	288	2496
3.25	144	144	3776	800	2336	800	3776	800	1376	288	2336
3.5	0	144	2912	768	2144	768	2912	768	1088	288	2144
3.75	0	0	2176	736	1856	736	2176	736	800	256	1856
4	0	0	1536	736	1504	736	1536	736	576	256	1504
4.25	0	0	1088	704	1184	704	1088	704	384	256	1184
4.5	0	0	704	672	896	672	704	672	256	224	896

Table 42. Reference Performance minus Performance with Extended Upstream ROL System

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist		(FDM)				DBM			FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	-320	0	-64	0	-192	0	-32	0	-64	0	0	0
1	0	0	-1056	0	-384	0	-640	0	-64	0	-256	0	0	0
1.25	0	0	-2016	-32	-736	-32	-1216	-32	-64	0	-480	-32	0	0
1.5	0	0	-2976	-64	-1152	-64	-1792	-32	-96	0	-704	-32	0	0
1.75	0	0	-4224	-96	-1536	-96	-2528	-64	-64	0	-960	-64	0	0
2	0	0	-4832	-128	-1952	-128	-2848	-96	-64	0	-1216	-96	0	0
2.25	0	0	-5216	-192	-2208	-192	-3008	-128	-96	0	-1344	-128	32	0
2.5	0	0	-5280	-256	-2400	-256	-2976	-160	-128	0	-1440	-160	32	0
2.75	0	0	-4992	-288	-2464	-288	-2752	-160	-160	0	-1408	-160	96	0
3	0	0	-4416	-352	-2400	-352	-2368	-224	-192	0	-1312	-224	96	0
3.25	0	0	-3552	-448	-2272	-448	-1792	-288	-96	0	-1184	-288	128	0
3.5	144	-144	-2784	-480	-2112	-480	-1280	-288	-32	0	-1024	-288	160	0
3.75	0	0	-2112	-512	-1824	-512	-832	-288	32	0	-768	-288	160	0
4	0	0	-1504	-544	-1504	-544	-448	-320	64	0	-480	-320	160	0
4.25	0	0	-1088	-544	-1184	-544	-160	-288	96	0	-256	-288	128	0
4.5	0	0	-704	-544	-896	-544	64	-288	96	0	-64	-288	96	0
4.75	0	0	-416	-544	-576	-544	192	-288	96	0	128	-288	96	0
5	0	0	-192	-544	-320	-544	224	-256	64	0	224	-256	96	0

[0153] Extended Upstream Reduced Overlap (ROL) Spectrum Mode:

[0154] Described in the following is an Overlap OL Quad Spectrum System for high speed ADSL and an evaluation of its spectral compatibility according to the 2003 revised TTC-Soumusho spectral compatibility rules. The OL Quad Spectrum System combines an extended downstream Bandwidth PSD (from approximately 25.875 KHz up to approximately 3.75 MHz) and the G.992.5 Upstream PSD (with

steep side lobes of -95 dB per octave slope). The Quad spectrum Downstream channel total power preferably is equal to approximately 20 dBm. The following demonstrates that that the Quad Spectrum Overlap system has a smaller spectral compatibility impact than G.992.1 OL with protected systems. It is therefore preferable in some embodiments to deploy the Quad Spectrum Overlap System in the same quad as protected systems at longer range than G.992.1 OL.

[0155] Note that the values provided in the following Figures 49 and 50 and in Tables 55-60 are approximate, or mean values, and may have a variance of up to 10%.

[0156] Figure 49 and Table 43 disclose exemplary Overlap Quad Spectrum Downstream Mask features based on peak values.

[0157] Figure 50 and Table 44 disclose the G.992.5 Upstream Mask features based on peak values.

[0158] Table 45 provides the performance of protected systems in the presence of 5 g.992.1 OL systems disturbers.

[0159] Table 46 provides the performance of protected systems in the presence of five OL Quad Spectrum systems disturbers.

[0160] Table 47 provides the delta between the reference performance and the performance in the presence of five OL quad spectrum systems (Table 46).

[0161] Table 48 provides the delta between the reference performance and the performance in the presence of 5 OL quad spectrum systems (Table 46).

Table 43 OL Quad Spectrum Downstream Mask Definition, Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.log2.(f/4)"
25.875<f<1104	-38.3
1104<f<1622	"-38.3 - 14.75.log2.(f/1104)"
1622<f<3750	"-46.5 - 2.9.log2.(f/1622)"
f=3750	-76.5
f>3925	-101.5

Table 44. G.992.5 Upstream Mask Definition, Peak Values

Frequency (kHz)	PSD (dBm/Hz) Peak values
0<f<4	-97.5
4<f<25.875	"-92.5 + 21.5.log2.(f/4)"
25.875<f<138	-34.5
138<f<f_int	"-34.5 - 95.log2.(f/138)"
f_int<f<686	10log10(0.05683*f^(1.5))
f>686	-100

Table 45. Protected Systems Performance with 5 G.992.1 OL Systems (1 Intra-Quad,4 Inter-Quad)

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	7008	832	3008	832	7008	832	2592	288	3008	832	1088	288
1	144	144	6880	832	3008	832	6880	832	2528	288	3008	832	1088	288
1.25	144	144	6784	832	3008	832	6784	832	2496	288	3008	832	1088	288
1.5	144	144	6624	832	2976	832	6624	832	2432	288	2976	832	1088	288
1.75	144	144	6464	800	2976	800	6464	800	2400	288	2976	800	1088	288
2	144	144	6336	768	2976	768	6336	768	2336	288	2976	768	1088	288
2.25	144	144	6080	736	2944	736	6080	736	2240	256	2944	736	1088	256
2.5	144	144	5664	672	2912	672	5664	672	2080	256	2912	672	1056	256
2.75	144	144	5024	608	2880	608	5024	608	1856	224	2880	608	1056	224
3	144	144	4192	544	2816	544	4192	544	1536	192	2816	544	1024	192
3.25	144	144	3488	480	2688	480	3488	480	1280	160	2688	480	992	160
3.5	144	0	2848	384	2528	384	2848	384	1056	128	2528	384	928	128
3.75	0	0	2304	288	2272	288	2304	288	832	96	2272	288	832	96
4	0	0	1792	224	1984	224	1792	224	640	64	1984	224	704	64
4.25	0	0	1344	160	1568	160	1344	160	480	64	1568	160	576	64
4.5	0	0	960	128	1152	128	960	128	352	32	1152	128	416	32
4.75	0	0	672	96	832	96	672	96	224	32	832	96	288	32
5	0	0	416	64	544	64	416	64	128	0	544	64	192	0

Table 46. Protected Systems performance with 5 OL Quad Spectrum Systems (1 Intra-Quad,4 Inter-Quad)

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1	144	144	7072	832	3008	832	7072	832	2592	288	3008	832	1088	288
1.25	144	144	6944	832	3008	832	6944	832	2560	288	3008	832	1088	288
1.5	144	144	6880	832	3008	832	6880	832	2528	288	3008	832	1088	288
1.75	144	144	6816	832	2976	832	6816	832	2528	288	2976	832	1088	288
2	144	144	6688	800	2976	800	6688	800	2464	288	2976	800	1088	288
2.25	144	144	6560	768	2976	768	6560	768	2400	288	2976	768	1088	288
2.5	144	144	6304	704	2976	704	6304	704	2336	256	2976	704	1088	256
2.75	144	144	5888	672	2944	672	5888	672	2176	224	2944	672	1088	224
3	144	144	5280	608	2944	608	5280	608	1952	224	2944	608	1088	224
3.25	144	144	4416	512	2912	512	4416	512	1632	192	2912	512	1056	192
3.5	144	144	3712	448	2816	448	3712	448	1376	160	2816	448	1024	160
3.75	0	0	3104	352	2688	352	3104	352	1152	128	2688	352	992	128
4	0	0	2560	288	2496	288	2560	288	928	96	2496	288	896	96
4.25	0	0	2112	224	2240	224	2112	224	768	64	2240	224	800	64
4.5	0	0	1696	160	1920	160	1696	160	608	32	1920	160	704	32
4.75	0	0	1344	96	1536	96	1344	96	480	32	1536	96	576	32
5	0	0	1024	64	1216	64	1024	64	352	32	1216	64	448	32

Table 47. Reference Performance minus Performance with Five OL Quad Spectrum

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist			(FDM)				DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	-320	0	-64	0	-192	0	-32	0	-64	0	0	0
1	0	0	-1120	0	-384	0	-704	0	-64	0	-256	0	0	0
1.25	0	0	-2048	-32	-736	-32	-1248	-32	-64	0	-480	-32	0	0
1.5	0	0	-3040	-64	-1184	-64	-1856	-32	-96	0	-736	-32	0	0
1.75	0	0	-4320	-96	-1536	-96	-2624	-64	-128	0	-960	-64	0	0
2	0	0	-4992	-96	-2016	-96	-3008	-64	-128	0	-1280	-64	0	0
2.25	0	0	-5472	-128	-2336	-128	-3264	-64	-160	0	-1472	-64	0	0
2.5	0	0	-5600	-128	-2624	-128	-3296	-32	-256	32	-1664	-32	-32	32
2.75	0	0	-5408	-160	-2784	-160	-3168	-32	-320	64	-1728	-32	-32	64
3	0	0	-4960	-160	-2848	-160	-2912	-32	-416	64	-1760	-32	-64	64
3.25	0	0	-4192	-160	-2848	-160	-2432	0	-352	96	-1760	0	-64	96
3.5	0	-144	-3584	-160	-2784	-160	-2080	32	-320	128	-1696	32	-96	128
3.75	0	0	-3040	-128	-2656	-128	-1760	96	-320	128	-1600	96	-160	128
4	0	0	-2528	-96	-2496	-96	-1472	128	-288	160	-1472	128	-192	160
4.25	0	0	-2112	-64	-2240	-64	-1184	192	-288	192	-1312	192	-224	192
4.5	0	0	-1696	-32	-1920	-32	-928	224	-256	192	-1088	224	-288	192
4.75	0	0	-1344	0	-1536	0	-736	256	-256	192	-832	256	-288	192
5	0	0	-1024	0	-1216	0	-608	288	-224	192	-672	288	-256	192

Table 48. G.992.1 OL SC Table minus Quad Spectrum OL SC Table

	TCM-ISDN		G.992.1 Annex A		G.992.2 Annex A		G.992.1 Annex C				G.992.2 Annex C			
Dist		(FDM)				DBM			FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75	0	0	-96	0	0	0	-96	0	-32	0	0	0	0	0
1	0	0	-192	0	0	0	-192	0	-64	0	0	0	0	0
1.25	0	0	-160	0	0	0	-160	0	-64	0	0	0	0	0
1.5	0	0	-256	0	-32	0	-256	0	-96	0	-32	0	0	0
1.75	0	0	-352	-32	0	-32	-352	-32	-128	0	0	-32	0	0
2	0	0	-352	-32	0	-32	-352	-32	-128	0	0	-32	0	0
2.25	0	0	-480	-32	-32	-32	-480	-32	-160	-32	-32	-32	0	-32
2.5	0	0	-640	-32	-64	-32	-640	-32	-256	0	-64	-32	-32	0
2.75	0	0	-864	-64	-64	-64	-864	-64	-320	0	-64	-64	-32	0
3	0	0	-1088	-64	-128	-64	-1088	-64	-416	-32	-128	-64	-64	-32
3.25	0	0	-928	-32	-224	-32	-928	-32	-352	-32	-224	-32	-64	-32
3.5	0	-144	-864	-64	-288	-64	-864	-64	-320	-32	-288	-64	-96	-32
3.75	0	0	-800	-64	-416	-64	-800	-64	-320	-32	-416	-64	-160	-32
4	0	0	-768	-64	-512	-64	-768	-64	-288	-32	-512	-64	-192	-32
4.25	0	0	-768	-64	-672	-64	-768	-64	-288	0	-672	-64	-224	0
4.5	0	0	-736	-32	-768	-32	-736	-32	-256	0	-768	-32	-288	0
4.75	0	0	-672	0	-704	0	-672	0	-256	0	-704	0	-288	0
5	0	0	-608	0	-672	0	-608	0	-224	-32	-672	0	-256	-32